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SOIL MOISTURE MEASUREMENT

Vaclav Lednicky and Vaclav Richter[1]

ABSTRACT: The author describes the construction and operation of the Gallenkamp tensiometer (2 models) and presents the results of soil moisture measurements taken at the Ostrava--Poruba Station. The relationship between soil moisture measurements, atmospheric precipitation, and evaporation are discussed.

Plants absorb water in essentially two ways, the most predominant of /28* which is the direct absorption of water from the soil by roots. The soil then is the main water supply for plants and at the same time the means of changing rainwater into physiologically active water, if we do not take into account the bioclimatic significance of water vapor in the air or ground [7]. Water in plants serves as a substance for photosynthesis assimilation, it is the vehicle for conveying individual nutrients and it patricipates in the thermoregulation of the plant organism. In addition, water in the soil acts as a pedogenic agent by its loosening, hydrologic and translocational effects. These numerous important functions which water performs in the soil gives it its decisive role in soil fertility; together with warmth and nourishment, it comprises the limiting factor which /29 determines the height and quality of harvest of the crop grown. Regular observation of soil moisture with the help of individual methods by means of the same equipment would bring great benefit since soil moisture is of interest to not only farmers but also pedogenists, agrometeorologists, hydrologists and builders. Soil moisture is currently monitored by agrometeorologic reports at meteorological stations where it is observed three times weekly with early morning readings at the surface of the soil and at a depth of 10 cm in the cultivated land. | The soil moisture is assessed according

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* Numbers in the margin indicate foreign pagination.

[1] Of the HMU (Hydrometeorologic Institute).

to the appearance of the earth with regard to mechanical water retention and according to the feeling evoked by the earth in contact with the dry bare hand. We then classify the soil as wet, cool damp, dry or arid soil. This classification is taken from the simple scheme of determination of soil moisture in the ground during pedological research [6]. Since this determination of soil moisture is very rough, highly subjective and difficult to differentiate, we suggest the establishment of a network of stations to monitor soil moisture. This essentially concerns furnishing fixed base or auxiliary stations with instrumentation since in the majority of cases their location fulfills the conditions which it is necessary to maintain so that this observation data will be respected by a wider community [10]. From experience in neighboring countries [8, 10] it is very advantageous to use fixed climatological stations since it is possible to compare the influence of all meteorological elements on soil dampness and especially the effect of precipitation and evaporation.

All methods serving to establish soil moisture can be divided into two groups, the first of which consists of methods of working with soil samples removed from the earth and the second of which consists of methods of measuring water content in the soil deposit. On an experimental tract at the Ostrava HMÚ center between May and October 1968, soil dampness was measured in the natural deposit (*in situ*) by the tensiometric method, which is based on the principle of determining capillary tension of water in the soil [10]. The tensiometer is essentially a manometer modified for measuring absorbent pressures of soil less than atmospheric pressure [14] and serves for direct determination of matrix potential in soil whose value increases with a decreasing soil moisture according to dependences which are determined by physical and chemical properties of the soil [15]. In our measurements we used model SH-080 tensiometers manufactured by the British firm of Gallenkamp (Figures 1 and 2) which are designed for continual measurement of soil moisture at any depth from 8 to 61 cm below the surface. The tensiometer sensor is a special porous bowl filled with distilled water and inserted in the soil for the duration of the observation period. The bowl is cylindrical with a rounded bottom. Connection of the bowl with a

vacuum gauge is accomplished by a metal pipe with a waterproof rubber insert. The actual gauge has a built-in calibrated scale from 0 to 60 cm Hg with a small-diameter pipe that extends down into the metal stem for the purpose of increasing the sensitivity of the instrument. The instrument is shipped with a tank of water in which the porous chamber is enclosed to form a waterproof container so as to protect against loss of water through evaporation in transit and in storage. Operation of the instrument depends upon the tension of soil moisture which is caused by surface tension of the film of water surrounding elements of soil [13]. This tension fluctuates according to the moisture content, size of soil elements and soil compaction. In any given soil situation the latter two factors remain constant for the most part during a season, so we can say that changes in soil moisture tension indicated by the instrument depend primarily on changes in the moisture content. Submersion of the tensiometer sensor in the soil causes moisture tension by absorption of water from the porous bowl until equilibrium is reached between the water in the soil and the water in the bowl. Further drying out or dampening of the soil influences the increase or decrease, respectively, of moisture tension caused by water either leaving or entering the porous bowl, which is expressed by a change in value of the tension indicated in cm Hg by the gauge. This value is directly proportional to the force a root must overcome to extract water from the soil [12].

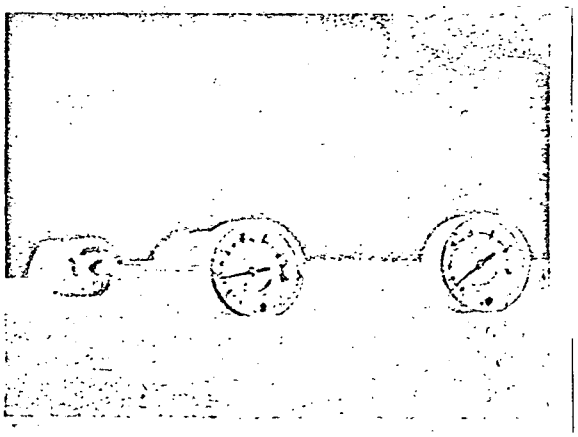

Figure 1. Soil Tensiometer. On the left is model SH-080, designed for measurement to depths of 30 [illegible] the right is model SH-090 with sensor for a depth of 61 cm.

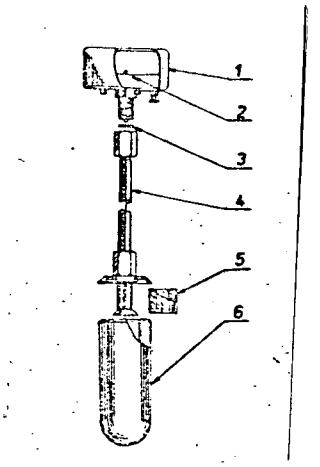

Figure 2. Diagram of the Tensiometer:
1. Protective Plastic Cover
2. Gauge
3. Upper Gasket
4. Connecting Metal Pipe
5. Lower Gasket
6. Tensiometer Sensor (Porous Container).

Installation of the tensiometer consists of insertion of the instrument into the bottom of a hole dug by shovel or earth borer and recovering with earth in the same order of strata. Prior to actual installation the waterproof cover is removed from around the porous bowl; the bowl is moved as little as possible so as not to block the pores. The depth of placement of the tensiometer sensor is assumed to be the distance from the center of the bowl to the soil surface. This distance can be checked at any time after installation by measuring from the underside of the gauge to the soil surface. The tensiometer must not be moved in the ground during use since a cavity would be created around the porous vessel and the data would be inaccurate. After one month's operation it is necessary to check the level of water in the pipe and, if necessary, top it up with distilled water either by use of special equipment (Gallenkamp catalog), a hypodermic syringe with a needle [14], or by means of a vacuum water pump. Where a tension of 30 cm Hg is not exceeded, as a rule the instrument will not require refilling during the course of the growing season. However, whenever the tension is higher than 55 cm Hg (especially in a dry spell), it is necessary to refill the tensiometer every 3 to 4 weeks to protect against trouble. The tensiometer may be left outside

even in winter, of course under the condition that a multiple layer of insulation is used. A thermally protected tensiometer can withstand a surface temperature of -13.3°C with a soil temperature of -1.1°C at the depth of the porous vessel. If, however, it is possible that the soil will freeze to the depth of the porous vessel, it is then necessary to remove the entire instrument. After seasonal use or relocation, the tensiometer's porous vessel should be sterilized in a 1 to 50 solution of formaldehyde, which will protect it from /30 contamination.

Results of measurement: a tensiometer was installed on April 28, 1968 in a cucumber patch of 400 m^2 total area. Areawise, the instrument was positioned approximately in the middle of the tract so the data could not be influenced by the surrounding area. Cucumbers of the "Bílské nakládačky" variety were planted by the 25th of May and their development was at first delayed by a drought which occurred at the end of June and the beginning of July and by an ensuing excessively wet growing season. It took until the second ten days in August to create a continuous supply of cucumbers. The middle section of the tensiometer was placed 20 cm below the soil surface, such that it showed us the force that the roots must develop in their active strata since most of the roots are spread out at the depth of 20 to 30 cm and the root network is the most dense here. The soil of the observed plot belongs to the brunizem type of soil, slightly podzol. Its mold is clayey to a thickness of 25 cm; the sediment has a clayey nature. A more detailed analysis of the soil was not conducted. The meteorological conditions extant in this period and influencing the condition of soil moisture are shown in Table 1.

TABLE 1. WEATHER DATA FROM THE OSTRAVA-PORUBA STATION FOR THE PERIOD APRIL--SEPTEMBER 1968.

	April	May	June	July	August	September
Average Monthly Air Temperature	9.5	12.0	17.4	17.1	17.0	13.8
Precipitation in mm	56.1	103.7	130.1	155.8	150.4	115.3
Evaporation in mm	--	--	97.7	105.9	63.7	43.7
Relative Air Humidity in %	69	77	73	74	80	85
Sunshine in Hours	209.4	179.2	229.8	202.1	166.9	138.4

With respect to the very rainy weather the soil was mostly damp to wet and thus the tensiometer data fluctuated predominantly around 12 to 14 cm Hg. Only in July did dry as well as damp periods occur and therefore as an example of daily movement of the individual elements that influence soil moisture the most we can illustrate the changes of soil moisture indicated by the tensiometer (Table 2).

TABLE 2.

Date	Ave. Daily Temp. °C	Precipitation in mm	Evaporation in mm	Soil Surface Cond. at 7:00 A.M.	Soil Moisture Tension in cm Hg	Soil Moisture at Depth of 10 cm
1	18.0	--	6.8	Dry	32	Dry
2	18.1	--	2.3	Dry	35	--
3	21.3	--	4.7	Dry	40	Arid
4	22.4	--	5.1	Dry	40	--
5	23.8	--	2.7	Dry	40	--
6	24.6	--	0.4	Dry	42	Arid
7	21.2	0.2	3.5	Dry	46	--
8	24.0	0.0	6.1	Dry	47	--
9	22.8	--	6.8	Dry	49	Arid
10	20.3	--	4.2	Dry	49	--
11	20.7	14.1	8.4	Dry	49	--
12	14.4	--	3.9	Damp	45	Dry
13	16.0	--	6.0	Damp	41	--
14	18.4	5.4	4.7	Dry	40	--
15	15.6	19.0	--	Damp	38	Dry
16	15.9	--	3.3	Damp	30	Moderately Damp
17	15.4	12.5	3.5	Damp	25	--
18	13.7	7.3	0.6	Damp	20	Damp
19	15.2	0.0	3.1	Damp	14	Wet
20	14.9	3.7	2.7	Damp	12	--
21	11.8	13.5	2.4	Damp	12	--
22	12.8	2.3	2.0	Damp	12	--
23	13.5	2.8	0.8	Damp	11	--
24	15.1	9.3	2.6	Surface Soaked	11	Wet
25	16.3	11.1	2.1	"	11	--
26	13.0	7.2	3.5	"	11	--
27	13.1	25.1	5.6	"	10	--
28	13.7	18.2	2.7	"	10	Wet
29	15.1	7.1	3.2	"	11	--
30	15.6	6.7	1.7	"	12	--
31	16.0	--	0.5	"	12	Wet

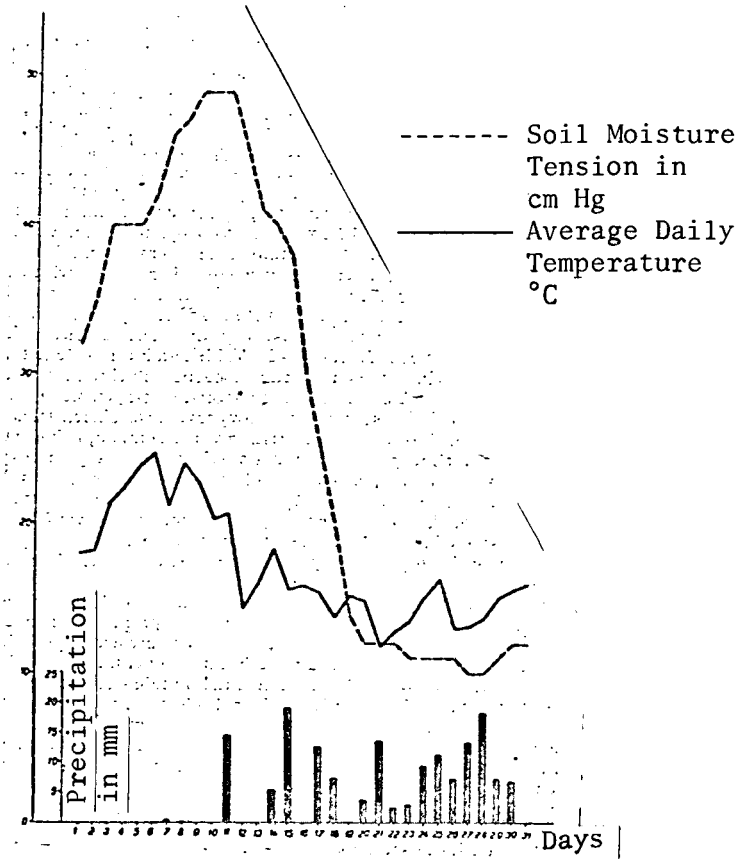

Figure 3.

The values of evaporation are determined by observation on Soviet-built model GGI-3000 evaporation gauges. Soil condition is determined by a key used in the weather net and soil moisture at a 10 cm depth is determined according to instructions for an agrometeorological station.

From the table of daily movement of selected elements it is evident that the tensiometer reliably ascertained the changes in soil moisture which depend primarily on atmospheric precipitation. Ground soil moisture, however, was picked in addition to soil condition, soil moisture and the amount of precipitation and its intensity. The influence of evaporation on changes in soil moisture less significance was discovered in our measurements, was probably due to the diverse nature of evaporation from free water level and soil. An example of the dependence of soil dampness on the weather is the course of increased tension of soil moisture in July of this year when, by the influence

of increased temperatures and evaporation, the soil moisture tension reached a value of 49 cm Hg. Showers, which occurred after July 11, caused such a drop in tension during the following days that by July 16 the tension was a mere 30 cm Hg and by July 20 it reached 12 cm Hg. This month was selected for illustration of the influence of weather on soil moisture because during this month there was a dry as well as a damp period and a similar situation has not recurred this year.

On the basis of our experience and measurement results we recommend the introduction of these very simple instruments at selected stations in various soil and climatic conditions. Uniform placement of the tensiometer vessel beneath the turf in the area of the station would ensure uniformity of the vegetation cover for the whole net and the measured values would be directly comparable with each other. In the interest of comparison with all methods, the tensiometer has the following advantages:

1. the instrument is very inexpensive and is mass produced in a number of countries (USA, USSR, England) and is under development here;

2. it does not require special operator instruction as for example the gamma-rays or neutron methods [2,3];

3. actual observation is very modest and consists in only daily reading of the indicator data;

4. the tensiometer measures properties of soil water that have a direct relationship to the work that plants must expend to extract water from the soil [12];

5. data concerning the tension of soil dampness are directly comparable with each other regardless of the type of soil, since each independent tension gives the same degree of usefulness of water for plants [13]; this merit of the /31 tensiometer is the most significant, i.e., moisture of various types of soil is difficult to compare on the basis of weight percentage which includes all categories of soil moisture and even water that is unreachable by plants [10];

6. with non-rapid changes of soil moisture the tensiometer will measure with a precision of 1 mm Hg; this precision is greater than that of other methods and is just as precise as the weight determination of water in soil [15];

7. with knowledge of the retention curves (pF curves) of the earth and the abovementioned measured values of the absorbent pressure it is possible to quickly and easily determine the soil moisture in percent by volume from the tensiometer reading [14];

8. by use of several tensiometers with bowls at various depths it is possible to follow quite well not only how water soaks into the soil from the surface, but also how it comes toward the surface in a dry period and thus document the influence of underground water on the regime of soil moisture.

One disadvantage of the tensiometer is its limited range, since the limits of sensitivity range from 0.8 atm [10] to 1.3 atm [15] of soil dampness tension and this fact reduces its use in dry regions in a period of long drought. Another disadvantage which is, however, common to all methods of soil moisture measurement is the need to calibrate the tensiometer data in relationship to the total quantity of water in the soil with respect to the fact that soil conditions are changing.

The merits of the tensiometer clearly outweigh its prospective deficiencies such that it is quite advantageous to use these instruments for observing soil dampness in the Hydrometeorological Institute's net. We suggest that each observation post be equipped with two tensiometers with bowls at 10 and 30 cm depths and in places with a higher level of subsoil water even to 60 cm. We believe this method is much more suitable for purposeful monitoring of soil moisture in the network than other methods, of which the most suitable would be the conductometric [4, 5] or thermal diffusion methods.

Conclusion: the continual method of measuring soil moisture by means of the tensiometer was tested and the authors recommend its use in the station net.

REFERENCES

1. Čabart, J., "Measurement of Soil Moisture Dynamics by the Horizontal Gamma Radiation Method," VÚM Scientific Project, Prague, 1964.
2. Čabart, J., "Measurement of Soil Moisture," *Vodní Hospodářství*, No. 5, 1967.
3. Danilin, A. I., "Measurement of Soil Moisture," *Agrometeorologii*, Moscow, 1958.
4. Hraško, J. et al., "Soil Analysis," Bratislava, 1962.
5. Kacvinský, M., "Evaluation of the Results of Electrical Resistance Method of Soil Moisture Measurements in Bratislava during 1952-1953," Collection of the Second National Meteorologic Conference, Prague, 1954.
6. Klika, J. and V. Novák, "The Practice of Plant Sociology, Soil Science, Climatology and Ecology," Prague, 1941.
7. Kosil, V. et al., "Soil Science," Prague, 1967.
8. Molga, "Concept of Soil Moisture Network Organization," Quebec, 1965.
9. "Introduction to Physics," Gallenkamp, London.
10. Razumova, L. A., "Basic Principles Governing the Organization of Soil Moisture Observations," Quebec, 1965.
11. Schildner, V., "Thermodiffusion Moisture Sensor," *Vodní Hospodářství*, No. 8, 1968.
12. Searle, S. A., "Plant Environment and the Grower," London, 1952.
13. Searle, S. A., "Plant Climate and Irrigation," London, 1954.
14. Semotán, Cízler, Kutilek, "The Practice of Pedologic Water Management," Prague, 1967.
15. Slavik, B. et al., "Method of Plant Water Transfer Study," Prague, 1965.

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